Predicting the Tropical Cyclone Genesis

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University of Hawaii

Acknowledgement: **Melinda Peng, Jim Hansen (NRL), X. Ge, B. Fu (UH)**

ONR support

- **Dynamical Approach**
- **Statistical approach**

Tropical Cyclone Conference, 4/29 – 5/1/09, Pearl Harbor, Hawaii

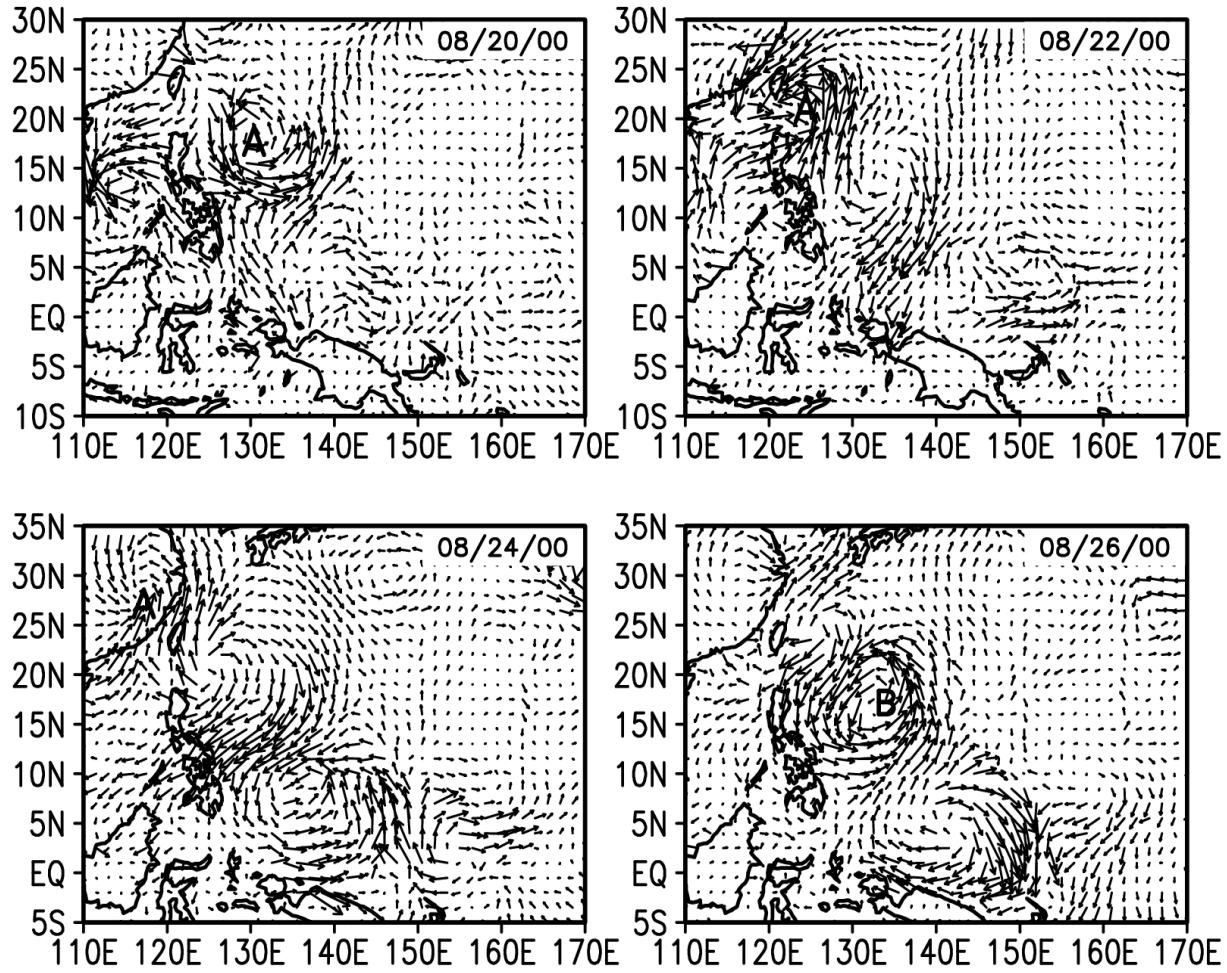
Real-case TC genesis forecast for Prapiroon (2000)

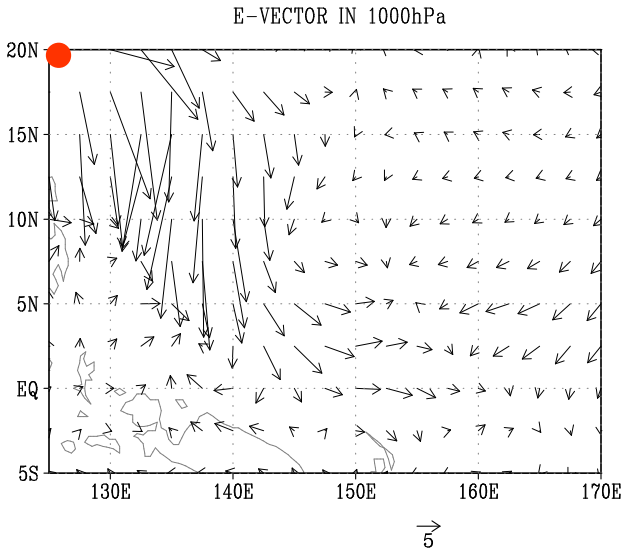
A typical case of TCED (TC Energy Dispersion)-induced cyclogenesis

A: TC Bilis; B: TC Prapiroon

Li and Fu 2006, JAS

Li et al. 2006, JAS





$$\vec{E} = \left(\frac{[\overline{v}^2 - \overline{u}^2]}{2}, [-\overline{u}\overline{v}'] \right)$$

3-8 day band pass-filtered surface QuikSCAT wind

20m/s

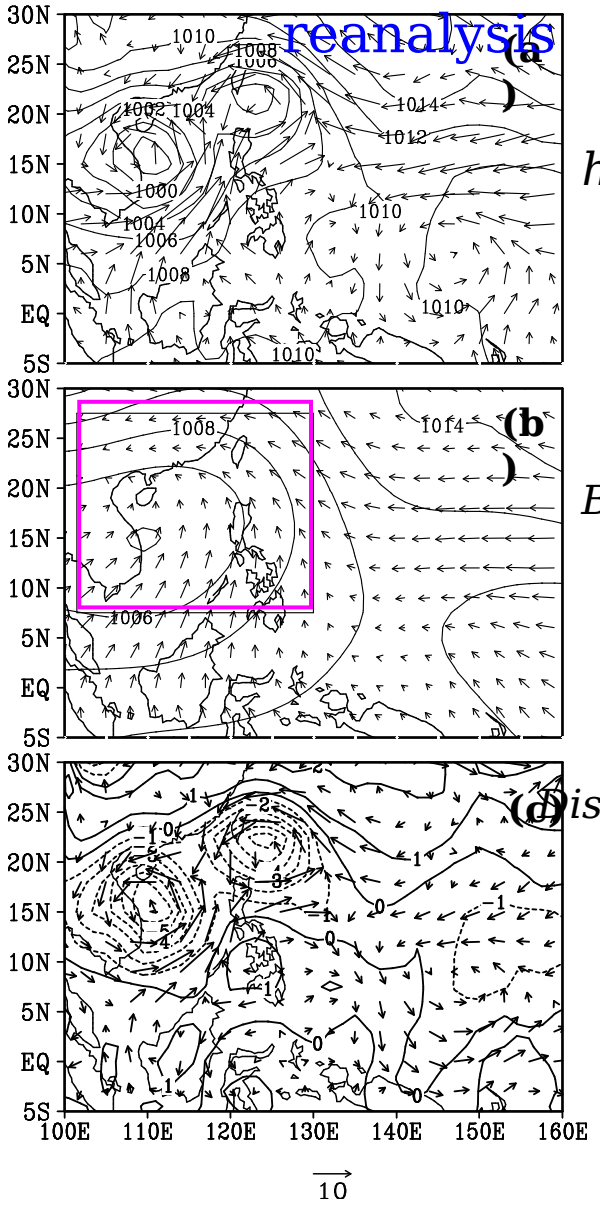
MM5 forecast experiment

CTL: retain the pre-existing TC Bilis

EXP: remove the pre-existing TC

Left: A spatial filter (Kurihara et al. 1993) is applied to extract the pre-existing TC vortex from the large-scale environmental flow. $h=h_B+h_D$.

Initial condition: NECP/NCAR reanalysis



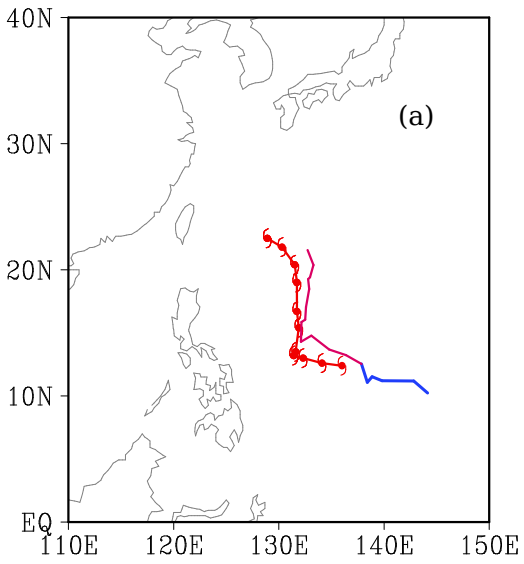
$h=h_B+h_D$

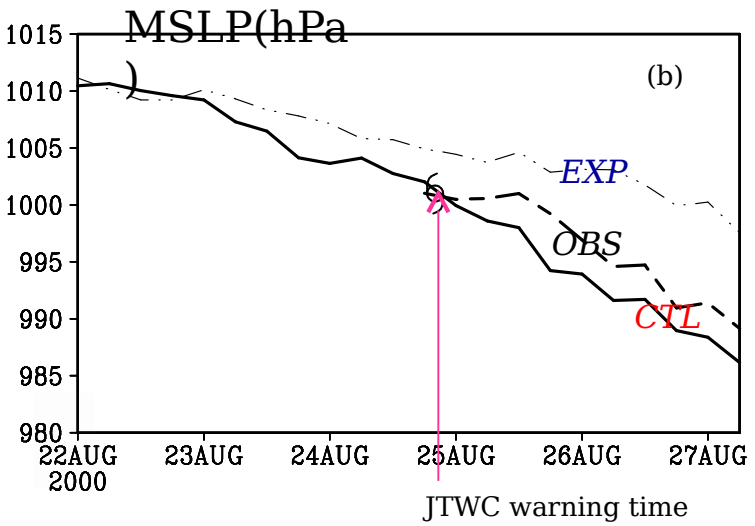
Basic field h_B

Disturbance field h_D

Ge, Li, Peng 2009, MWR

Forecasted TC intensity and track





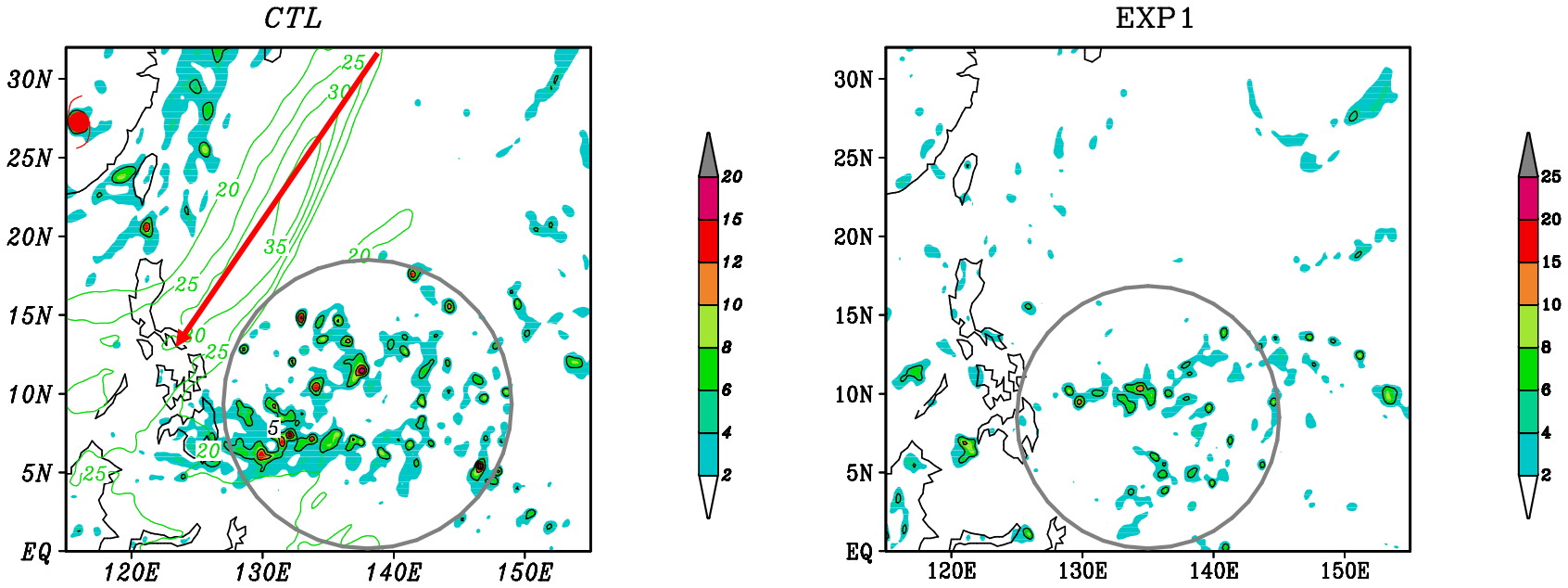
CTL: with pre-existing typhoon

EXP: without pre-existing typhoon

Through what process does the pre-existing typhoon affect the subsequent TC genesis and its intensity?

The upper level circulation

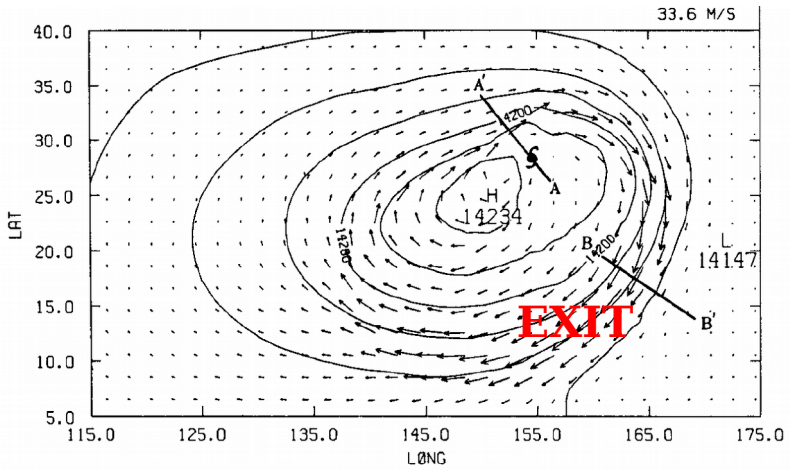
150-hPa **divergence field** ($\geq 2\times10^{-5}$ s^{-1} are **shaded**) and total velocity of **jet core (contour)** in CTL and EXP run at Hour 48

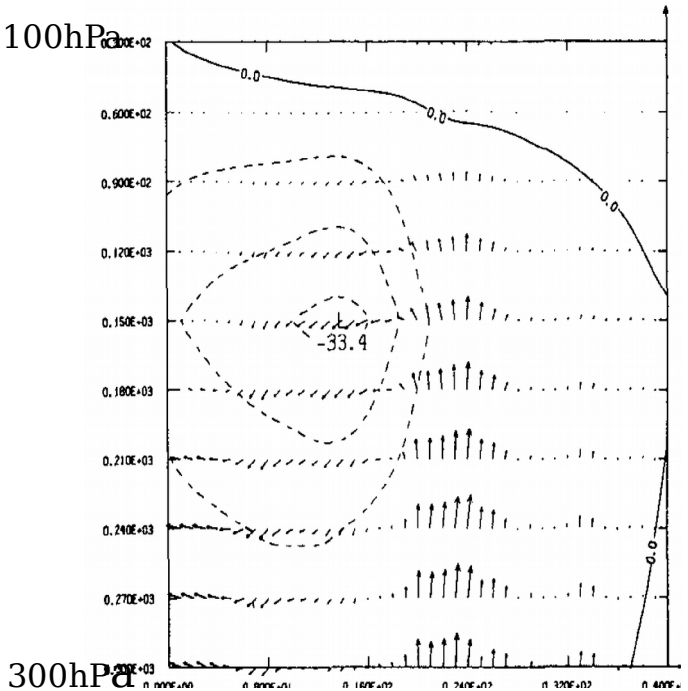


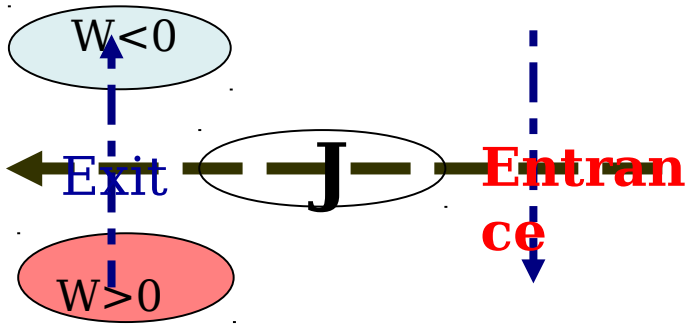
Enhanced upper-level divergence appears at left-exit side of the TC outflow jet.

Secondary circulation induced by upper outflow jet

Shi et al. (1990)







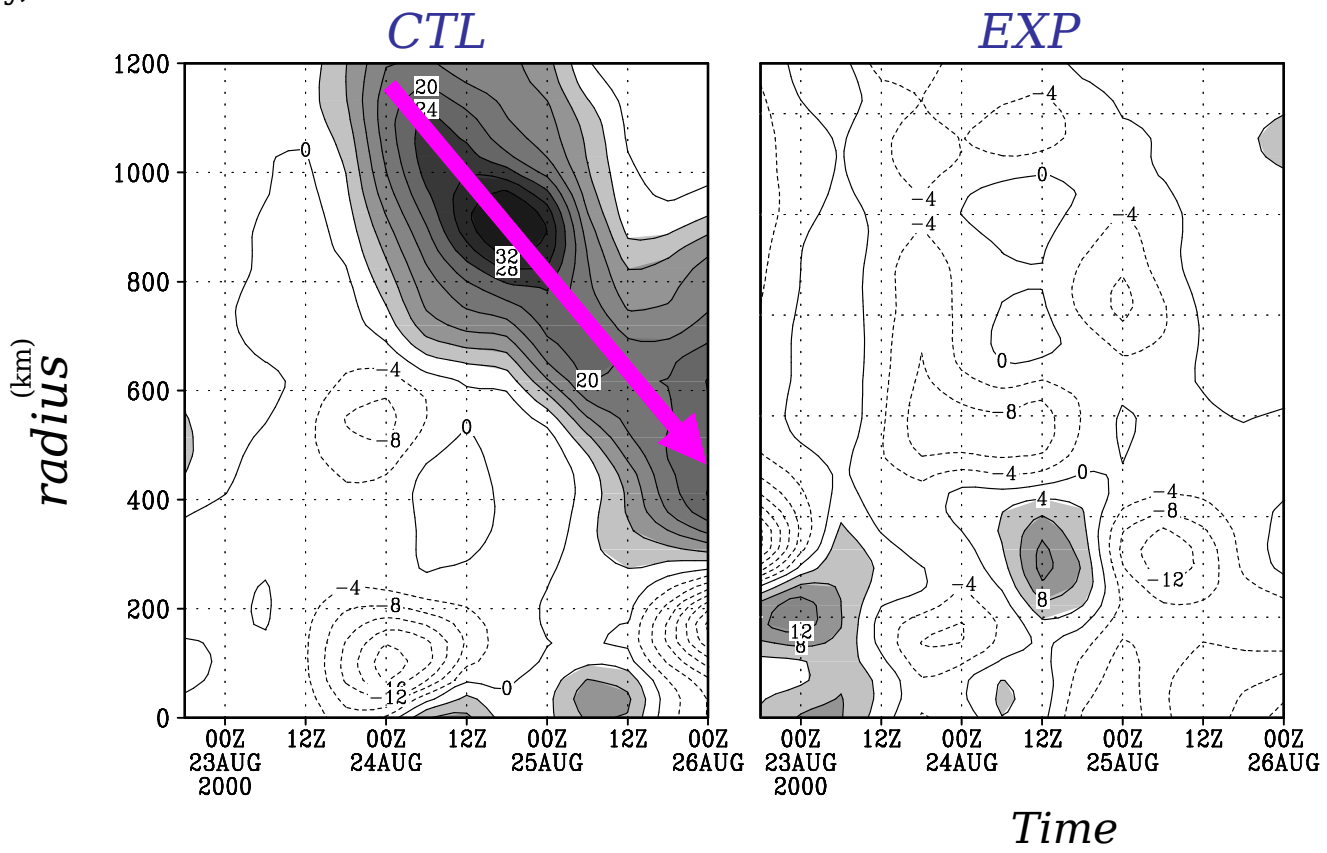
$$\frac{du_g}{dt} = fv_a$$

Upper-level eddy flux convergence of relative angular momentum (*EFC*)

$$EFC = -\frac{1}{r^2}\frac{\partial}{\partial r} r^2 \overline{u_L' v_L'}$$

Titley and Elsberry 2000

where u_L is the storm-relative radial velocity, v_L is the storm-relative tangential velocity, r is the radius.

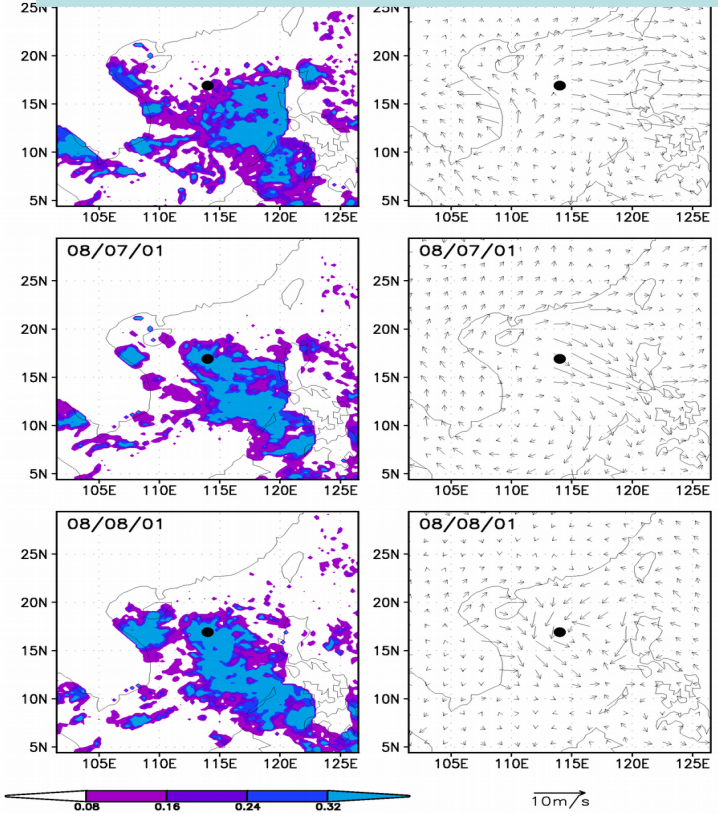


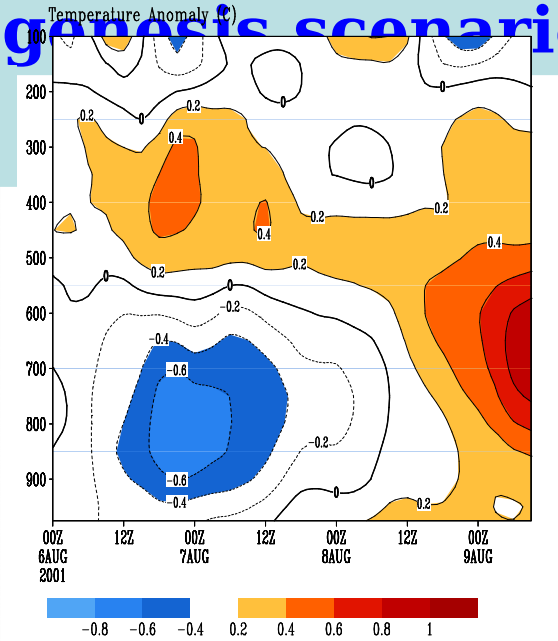
Radial-time cross section of 200-hPa EFC (contour interval: 4 m s^{-1} day^{-1}) in CTL (left panel) and EXP (right panel) run. The shaded areas indicate value greater than 4 m s^{-1} day^{-1}

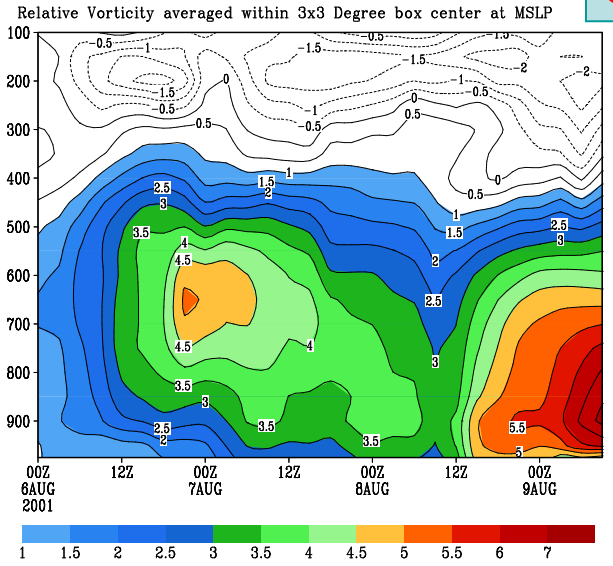
TC genesis associated with preexisting cloud cluster with no significant wind signals at the surface – **A top-down cyclogenesis scenario**

TMI liquid water

QuikSCAT wind





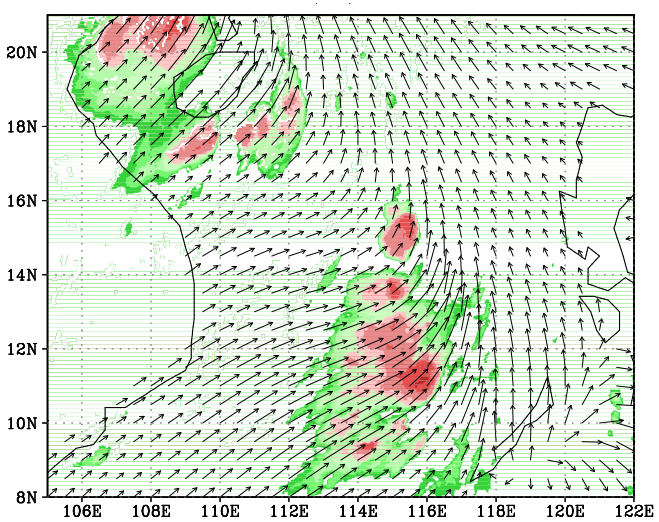


- **A cold core below the mid-level cyclone and a warm core above – A thermal wind relation**
- **A transition of the cold core to a warm core**
- **A formation of mid-level cyclone at 600mb**
- **A downward development of the mid-level cyclone prior to TC genesis**

enesis forecast with **cloud-resolving WRF** model

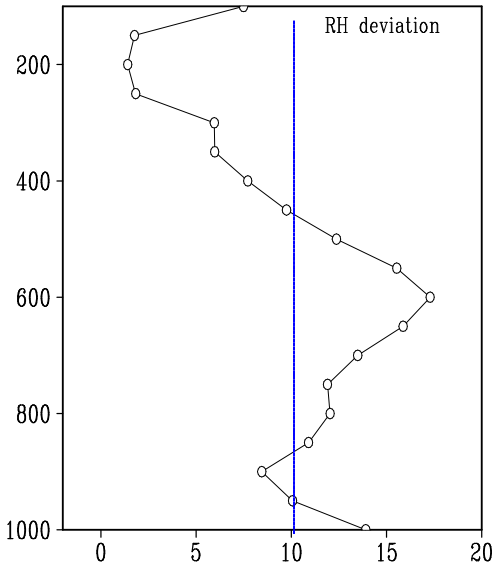
Typhoon Durian (2001)

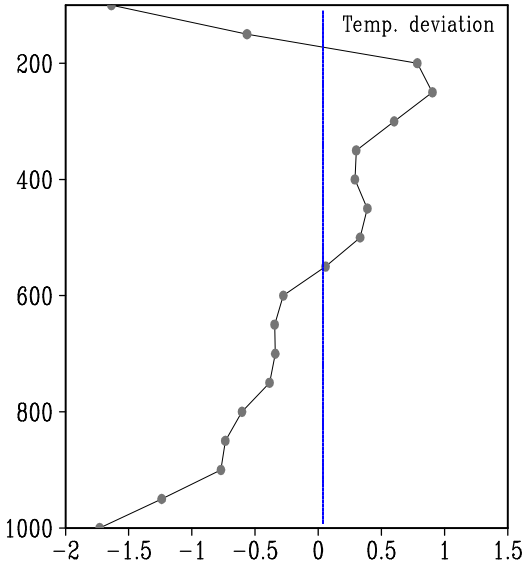
- **Horizontal resolution: 3 km**
- Explicit convection scheme
- **Initial condition** from 0000UTC **06/28/2001** (48hrs prior to **JTWC warning time 0000UTC**

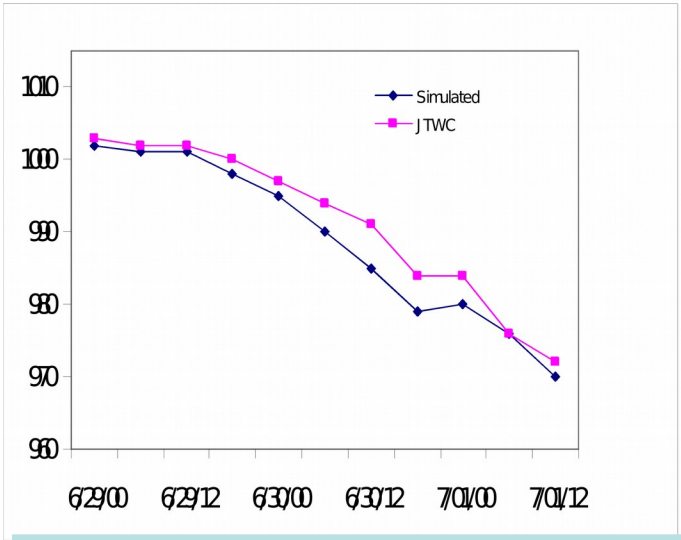


Observed surface wind (vector) and IR brightness temp. (shaded) at initial time

Vertical profile of moisture and temp anomaly at initial time

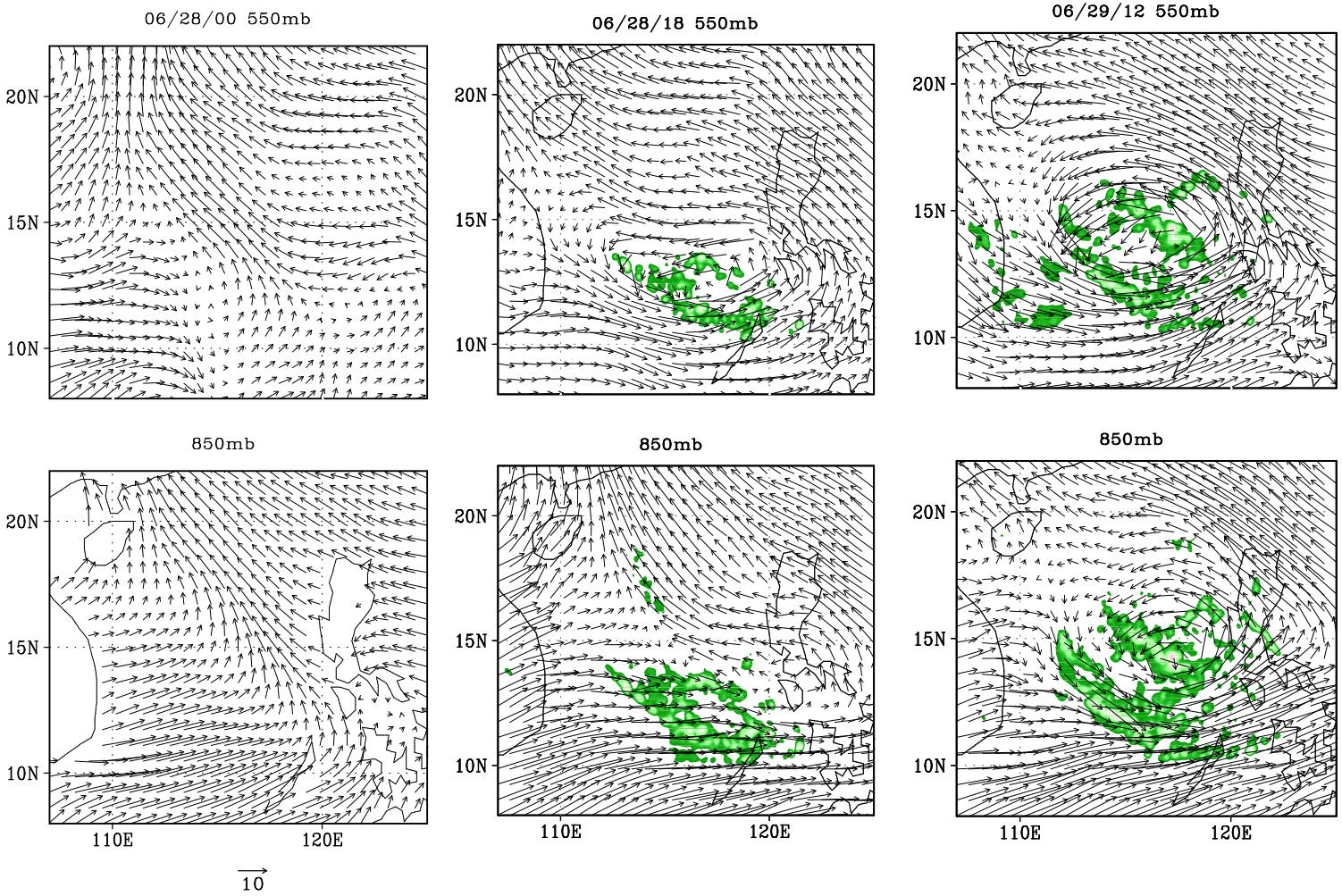






Real-case TC genesis forecast

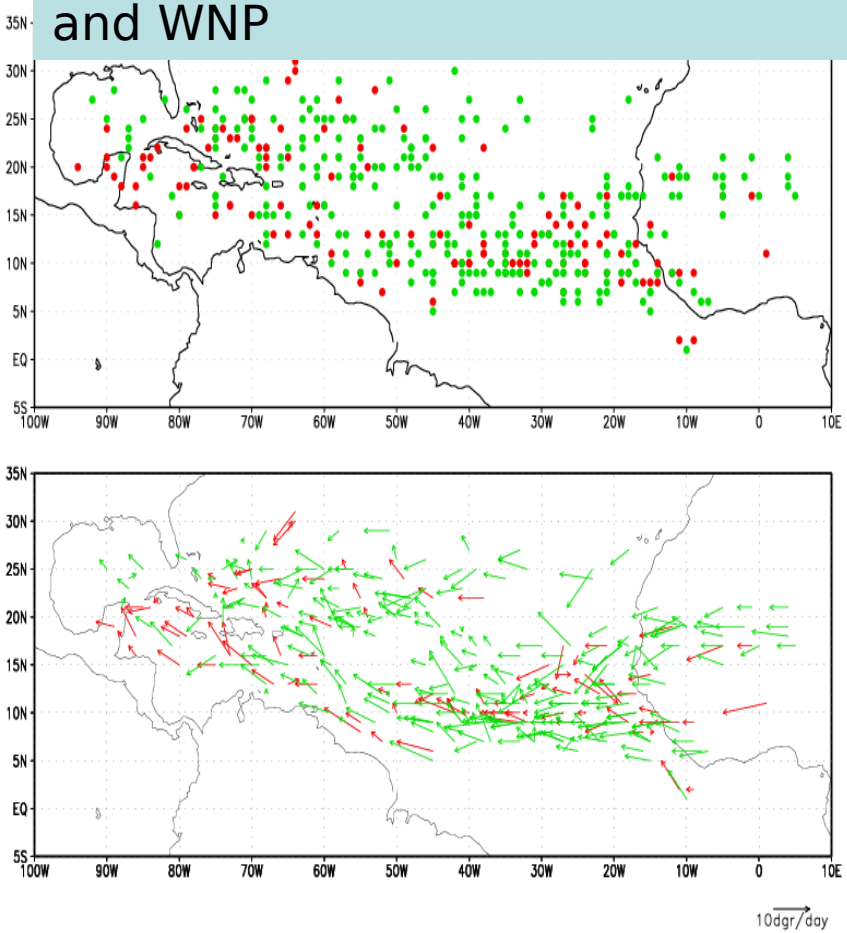
The model wind (vector) and cloud liquid water (shaded)

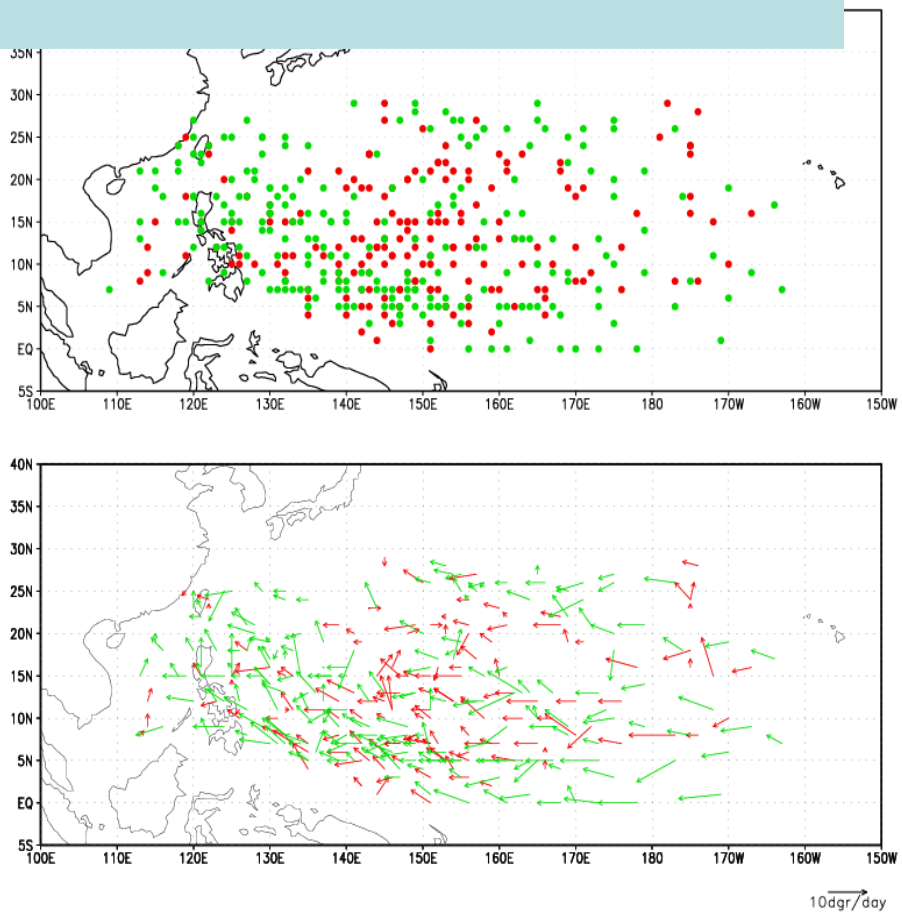


Statistical Method:

A logistic nonlinear regression model

Developing versus Nondeveloping Disturbances in North Atlantic and WNP





NA:

Dev:32 mvspd(ave): **5.29** degrees/s

Nondev:55 **6.22** degrees/s

WNP:

Dev:46 mvspd: **4.31** degrees/s

Nondev:41 **5.36** degrees/s

Only day -3, day -2, day -1 and day 0 for Dev cases

All the days during the lifespan for Nondev cases

Definitions

Developing cases:

Tropical storms reported in **JTWC** and NHC best track

The genesis date is the day when a TD formed with a max sustained wind over 25kts.

Nondeveloping cases:

Cyclonic circulations in 3-8-day filtered wind and relative vorticity fields with

(1) max vorticity > 1e-5

(2) mean radius > 400km

(3) lasting at least 3 days

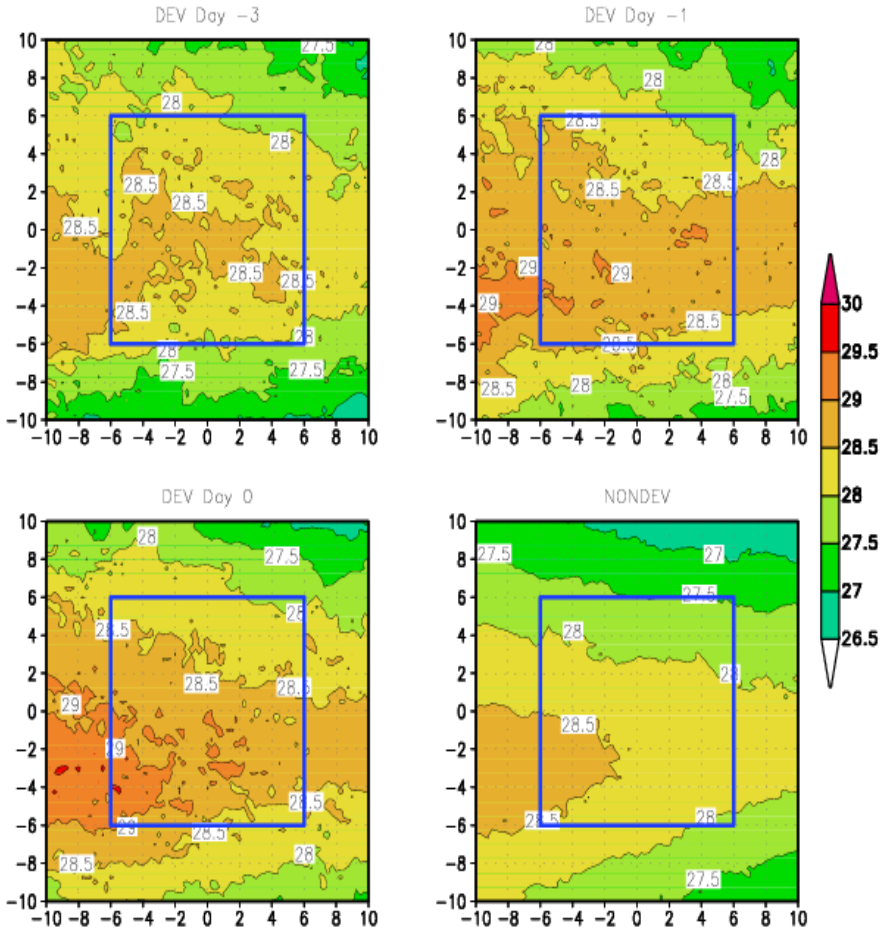
NA:	WNP:
Dev: 32	Dev: 46
Nondev: 55	Nondev: 41

Composites:

For Dev cases, we composite each case at day -3, day -2, day-1 and day0.

For Nondev cases, we composite all the days for all the selected

Composite of TMI SST



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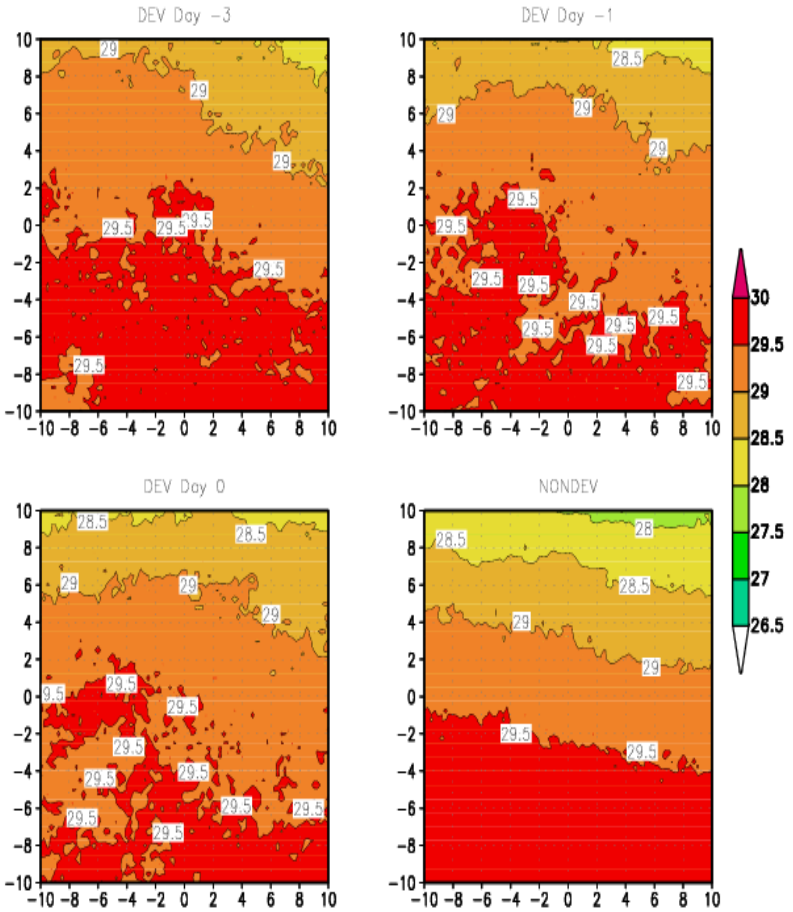
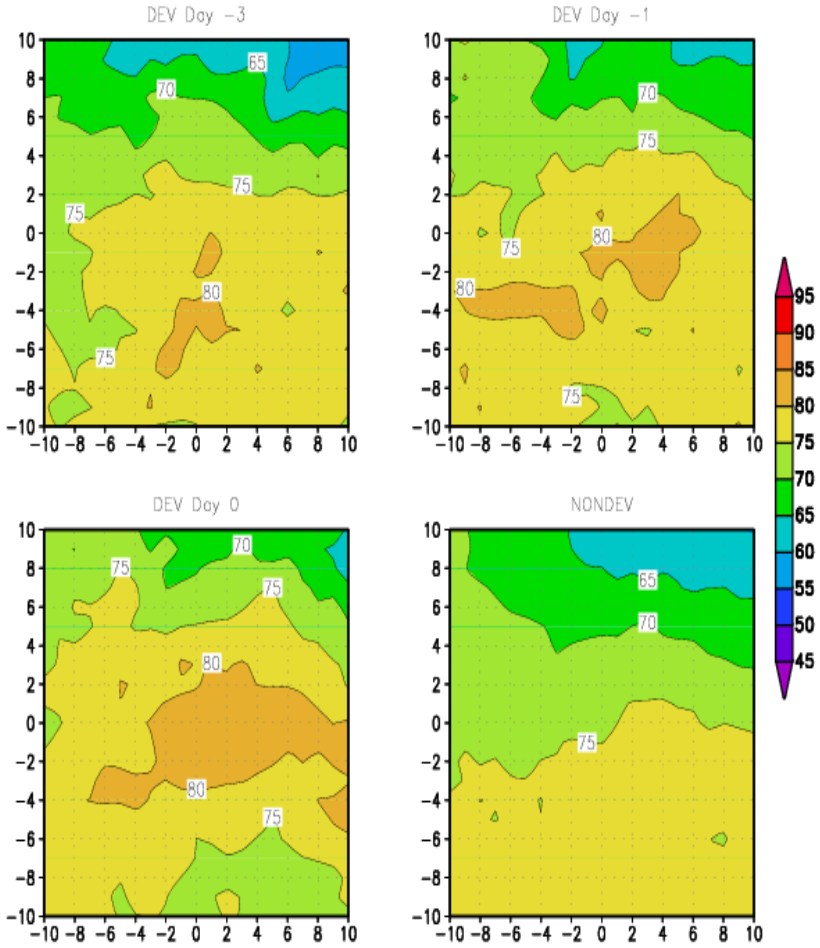


WNP

28.36°C, 28.59°C and 28.65°C vs 28.18°C

Composite of 850mb relative humidity



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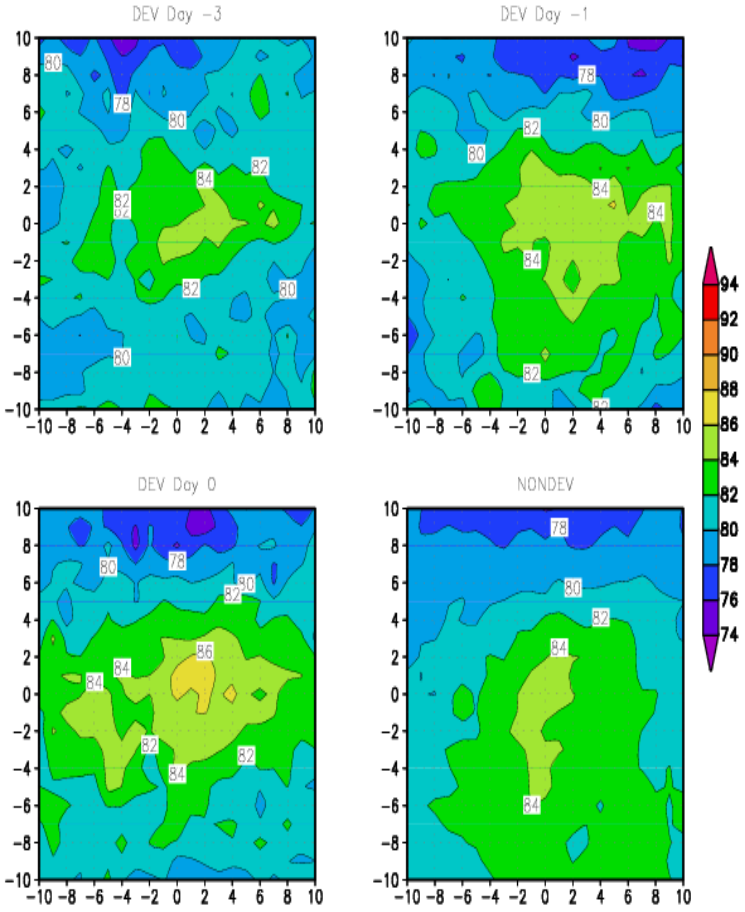
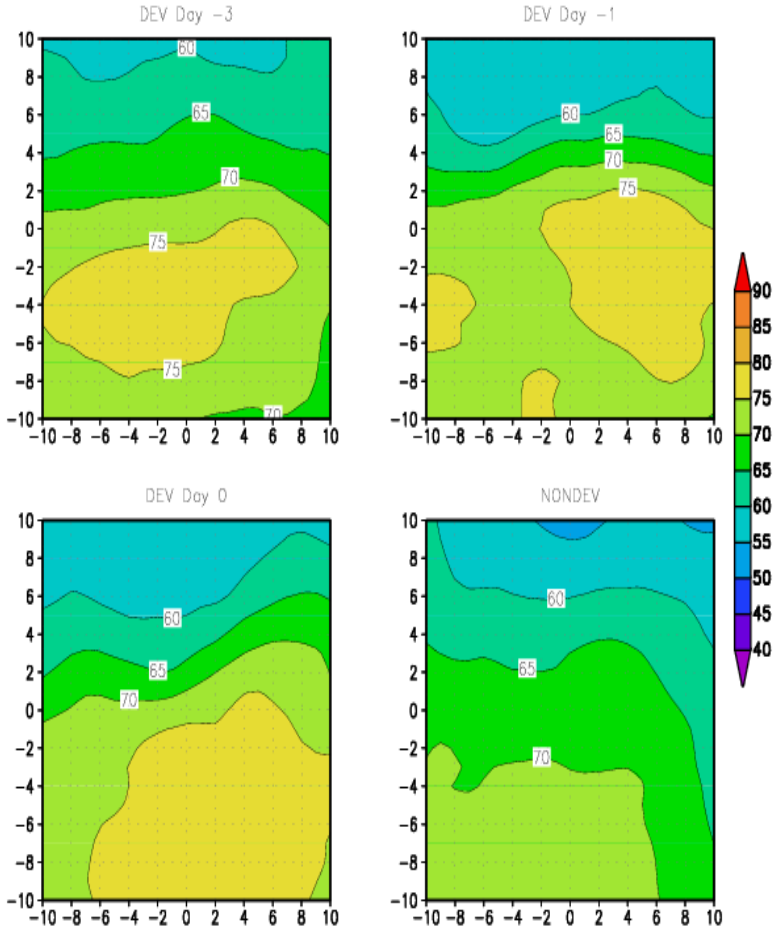


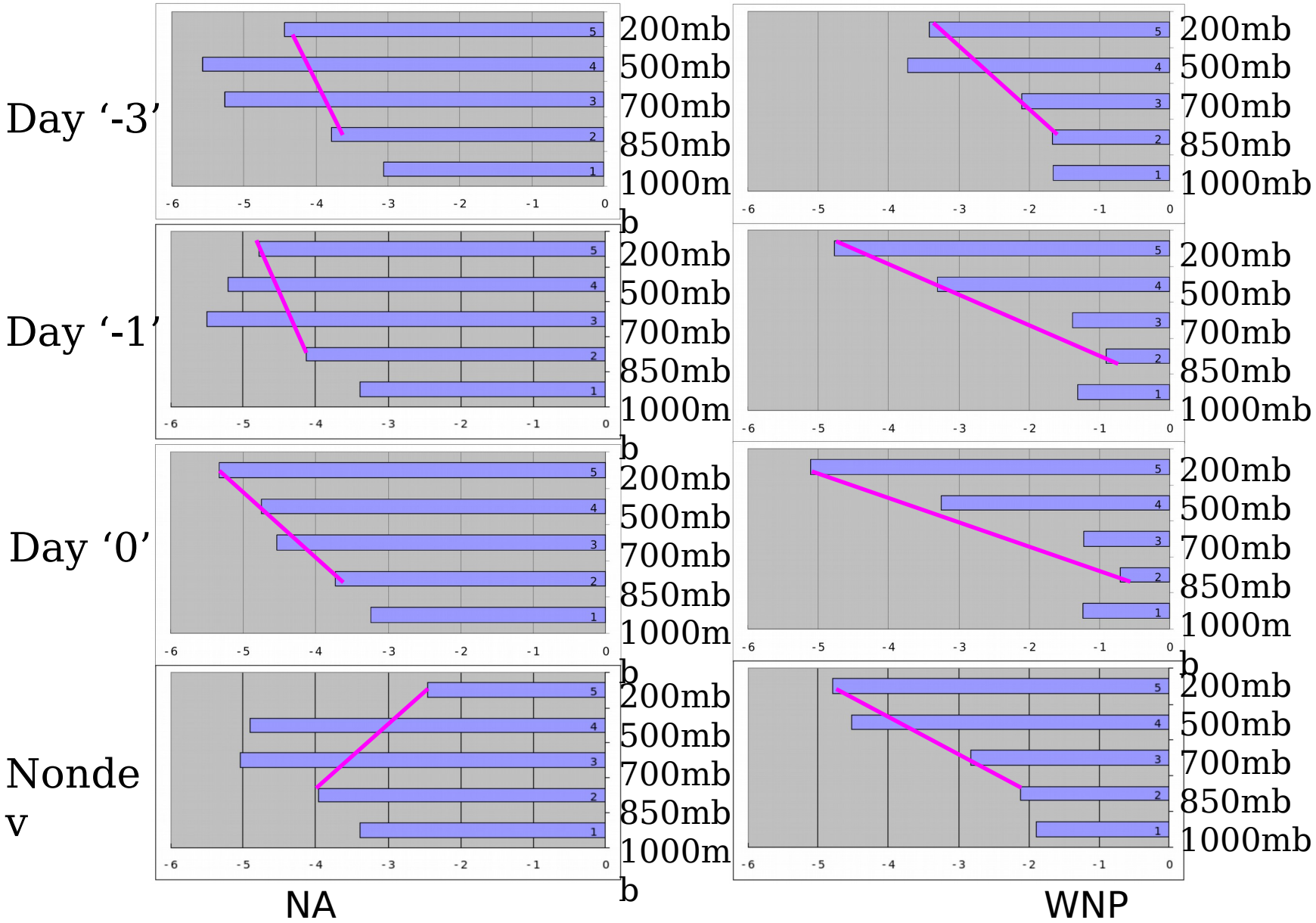
WNP

Composite of 500mb relative humidity

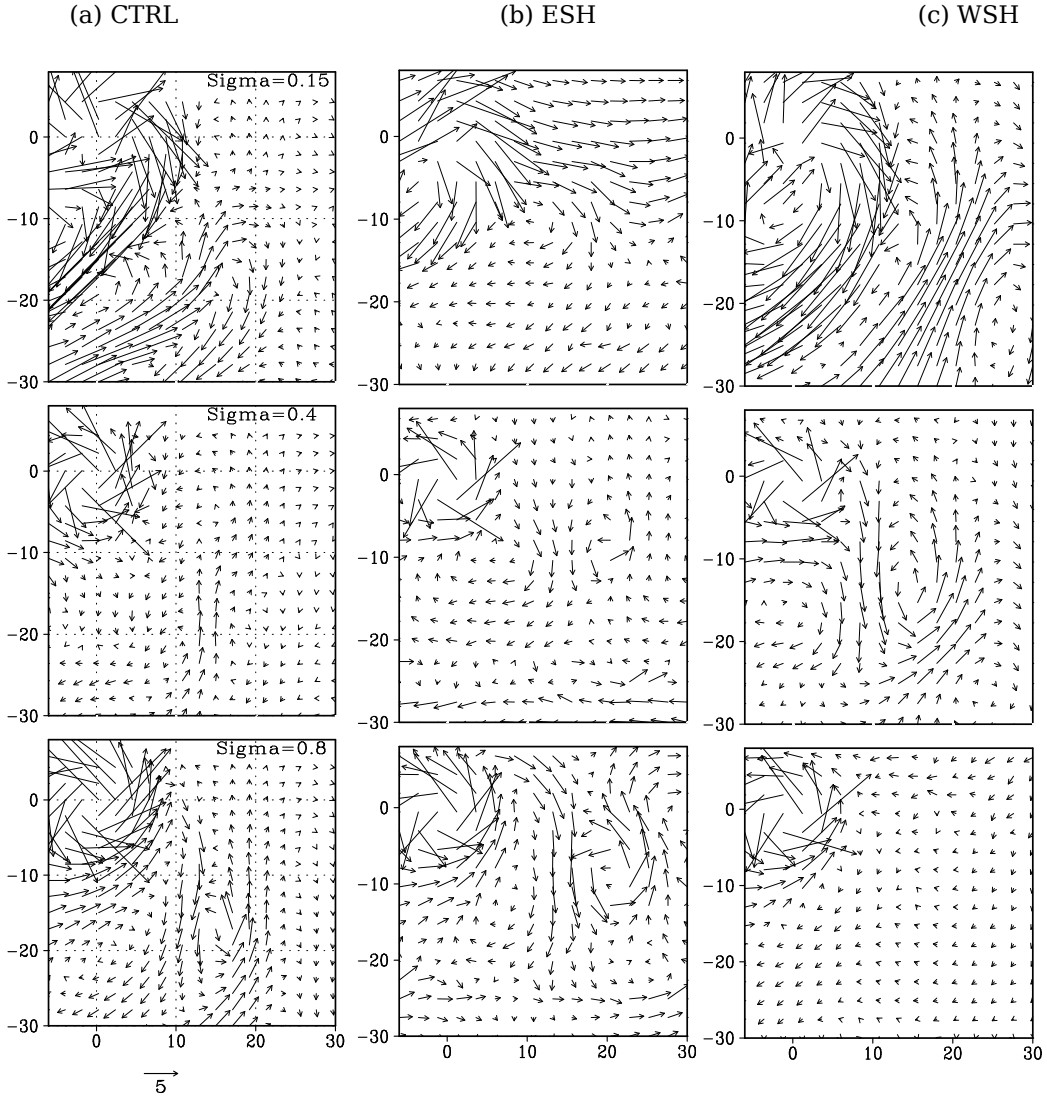


WNP

Vertical profile of 10° x10° domain averaged 20-day filtered U compone

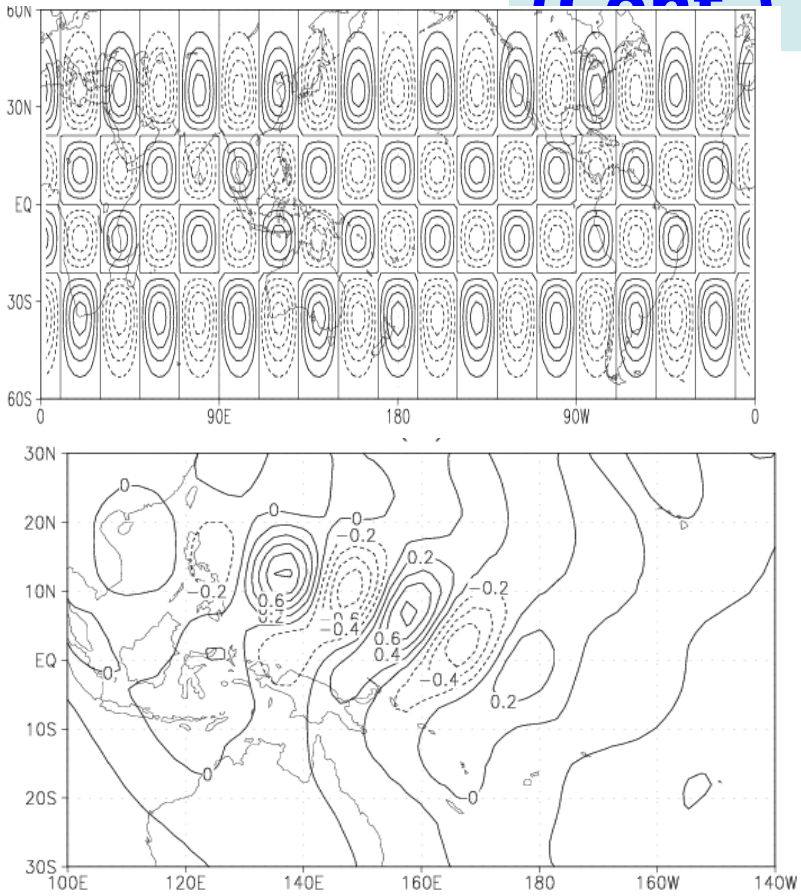


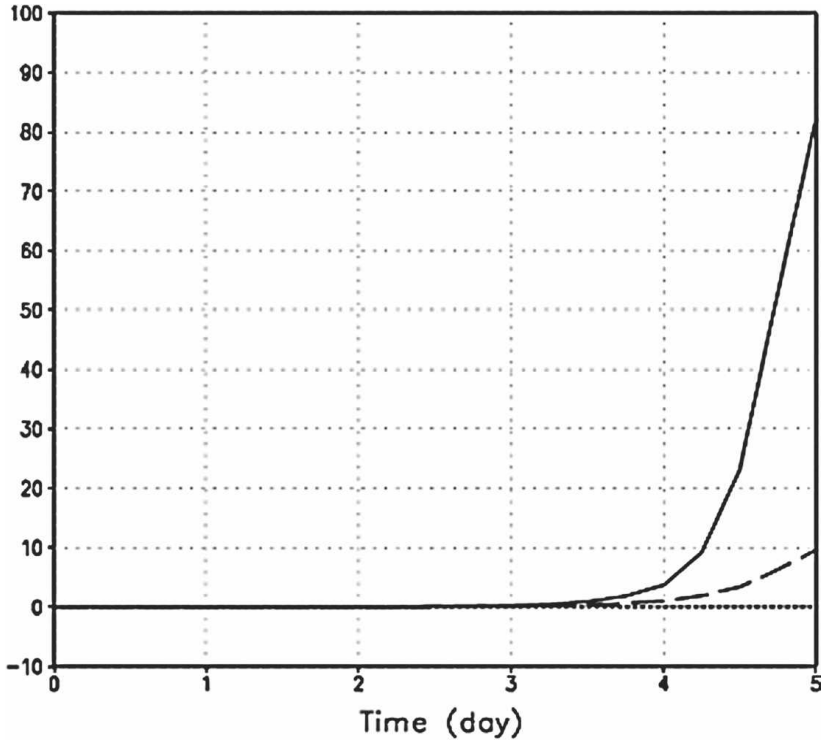
Easterly (westerly) shear favors the amplification of TCED-induced Rossby wave train in lower (upper) troposphere



Ge, Li, et al. 2007, GRL

The **vertical shear effect (Cont.)**





Left: Anomaly AGCM simulation with specified 3D summer (JJA) mean flows and SST and surface moisture condition

Right: Evolution of maximum perturbation kinetic energy under a constant easterly shear (solid line) and a constant westerly shear (dashed line).

Li 2006, JAS

Multiple linear regression method

Multiple linear regression attempts to model the relationship between two or more
explanatory variables and a response variable by fitting a linear equation to observed data.

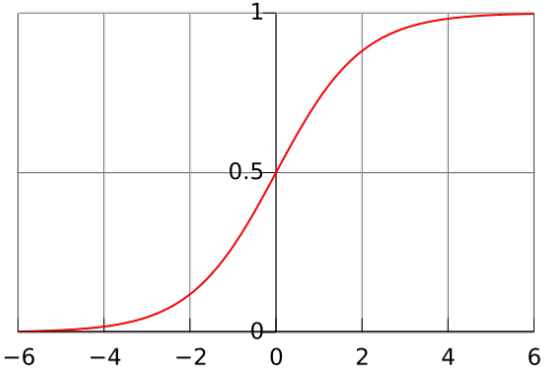
> **Formally, the model for multiple linear regression, given n observations, is**
> $y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \dots \beta_p x_{ip} + \varepsilon_i$ **for** $i = 1,2, \dots n.$

Logistic nonlinear regression method

stic regression is a model used for prediction of the probability of occurrence
vent by fitting data to a logistic curve. It makes use of several predictor variabl
may be either numerical or categorical.

$$f(z) = \frac{1}{1 + e^{-z}}$$

$$z = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots + \beta_k x_k,$$



vantages: (1) nonlinear
(2) used for both probability and deterministic forecasts

Logistic nonlinear regression model for WNP

1. Selected variables for WNP

Mvspd, vor850, div850, rhum500, T anomaly500, shear200-850

2. Predictors

x1=vor850 (max [10x10 box])
x2=vor850 (pattern correlation)
x3=div850 (ave [20x20 box])
x4=div850 (pattern correlation)
x5=rhum500 (ave [20x20 box])
x6=rhum500(pattern correlation)
x7=T anomaly500 (max [20x20 box])
x8=T anomaly500(pattern correlation)
x9=shear200-850 (ave [10x10] box])
x10=shear200-850(pattern correlation)
x11=mvspd

Composite of dev (day -1)

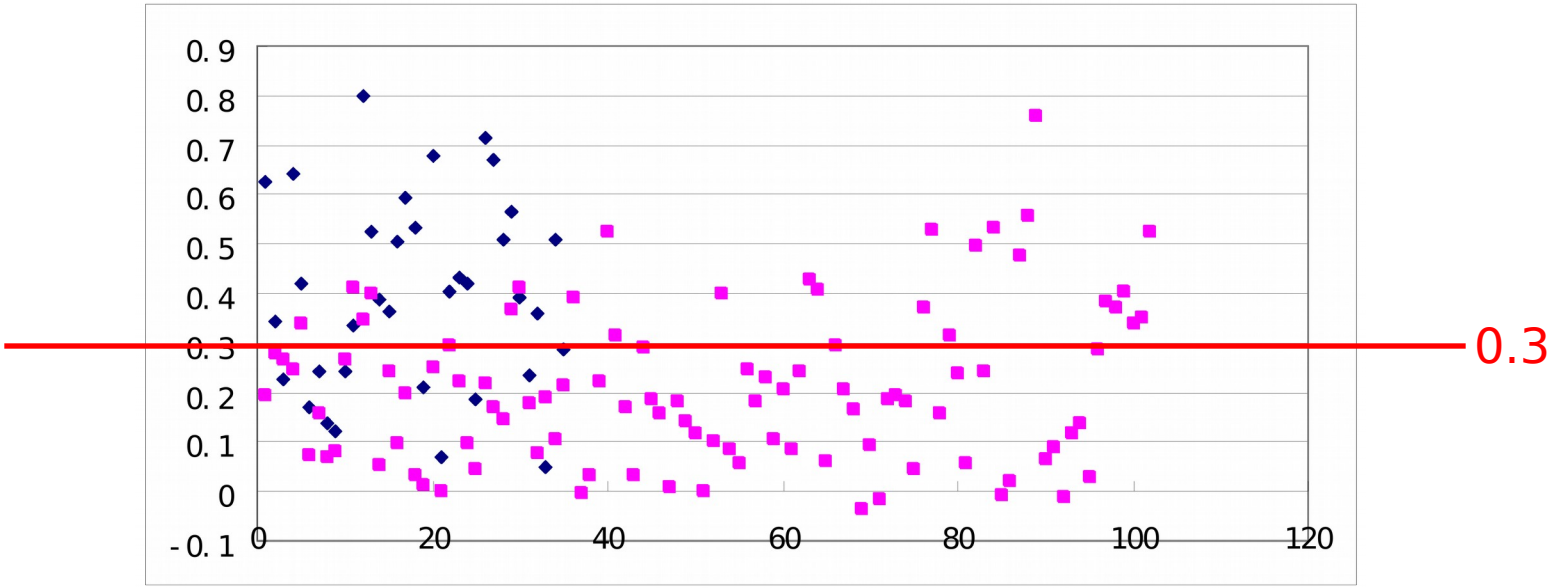
$$f(z) = \frac{1}{1 + e^{-z}}$$

$$z = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots + \beta_k x_k,$$

We use samples from 2003-2005 as the input to derive the prediction model.
Currently only to predict 24-48 hours TC genesis events

Model in-sample validation

(based on NOGAPS 2003-05 analysis data)



OBS / FCST	yes	no
yes	a=23	b=26
no	c=12	d=76

Hit rate= a/(a+c)=66%

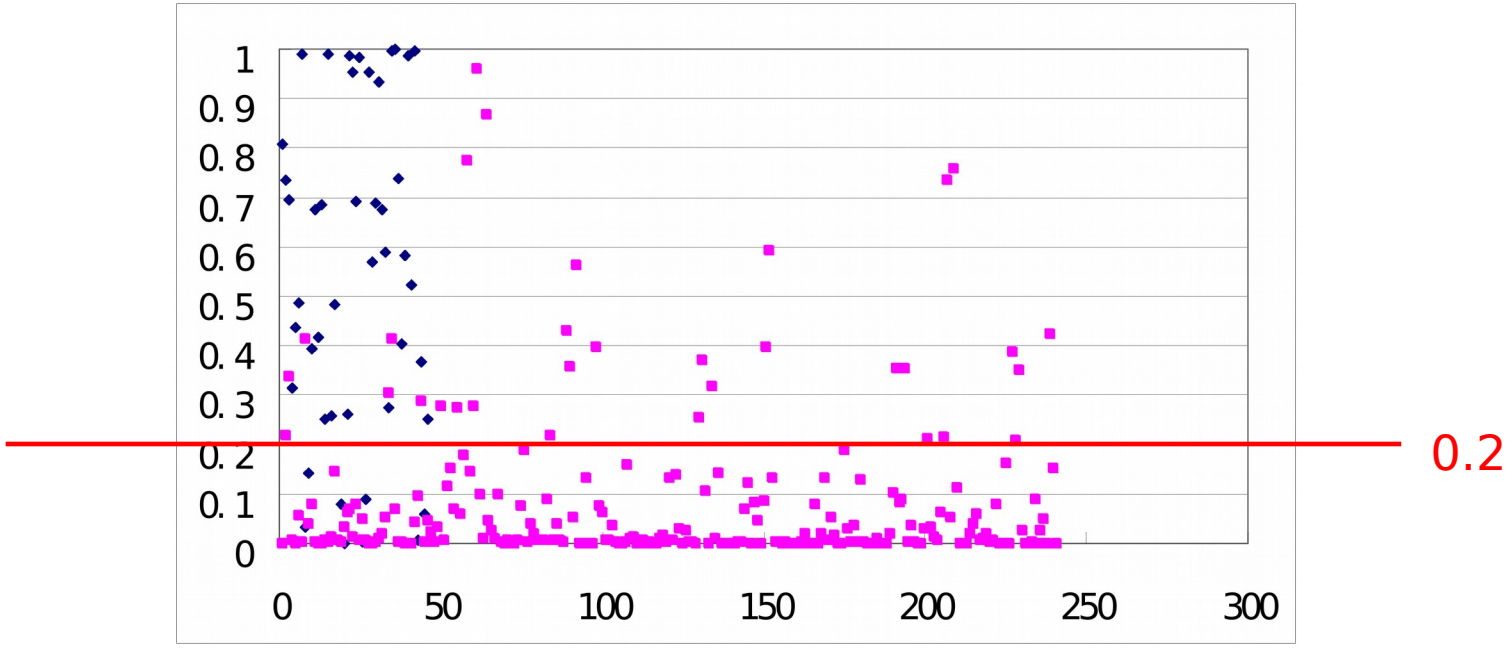
False alarm rate=b/(b+d)=25%

Miss rate=c/(a+c)=34%

Correct rejection=d(b+d)=75%

Bias ratio=(a+b)/(a+c)=1.4

Model in-sample validation (2003-2005)



OBS / FCST	yes	no
yes	a=37	b=32
no	c=9	d=209

Hit rate= a/(a+c)=80%

False alarm rate=b/(b+d)=13%

Miss rate=c/(a+c)=20%

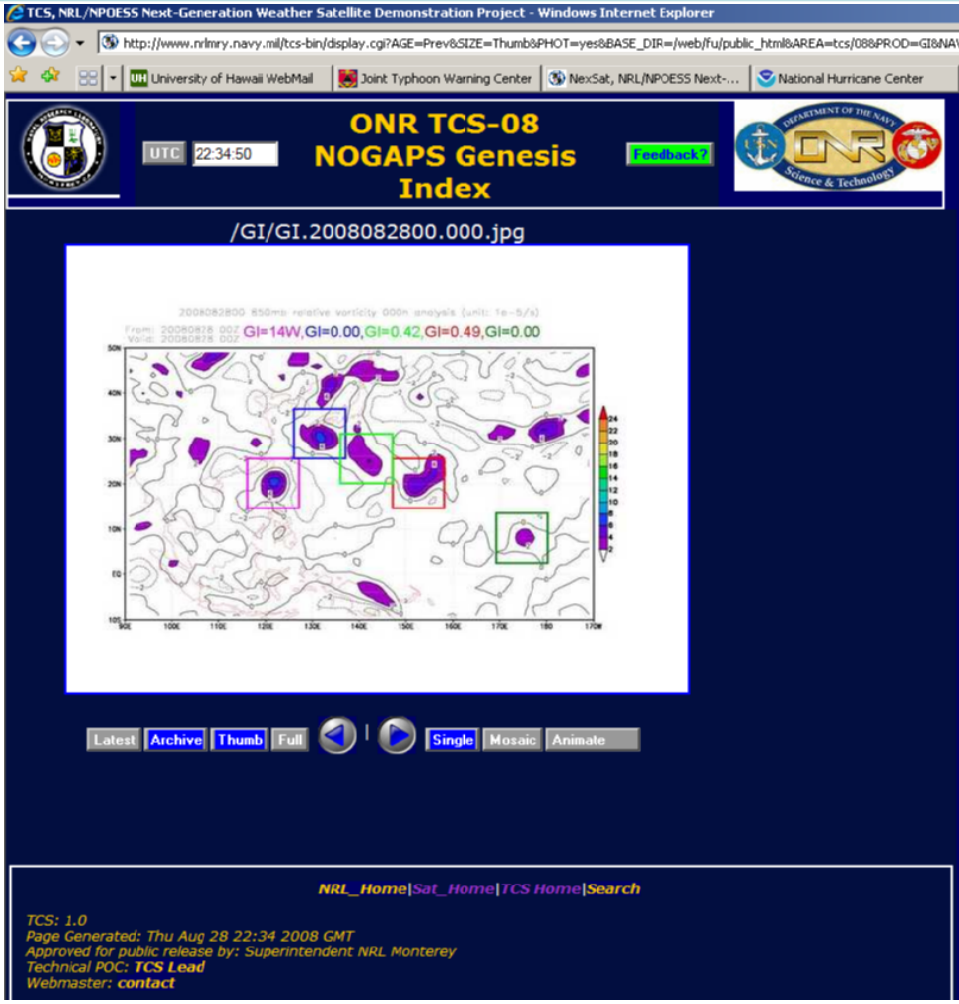
Correct rejection=d(b+d)=87%

Bias ratio=(a+b)/(a+c)=1.5

ne WNP real-time cyclogenesis forecast during TCS-

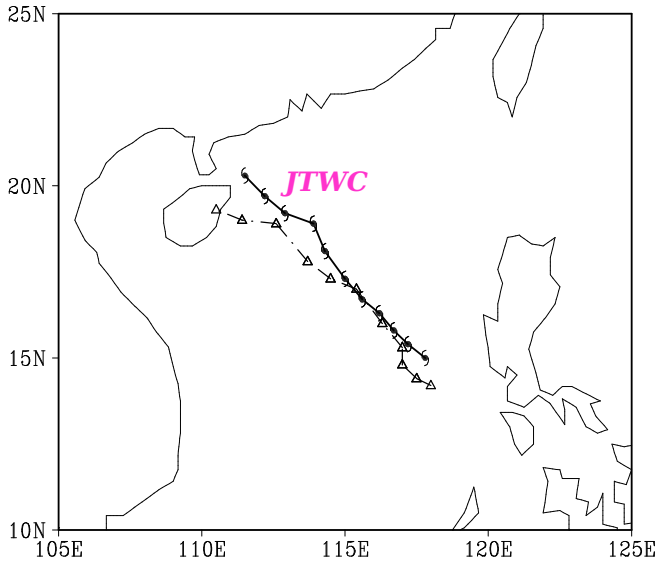
- Identify each disturbance in WNP during TCS-08
- Calculate the Genesis Potential Index (GPI) for each disturbance
- Posted the forecast in NRL website

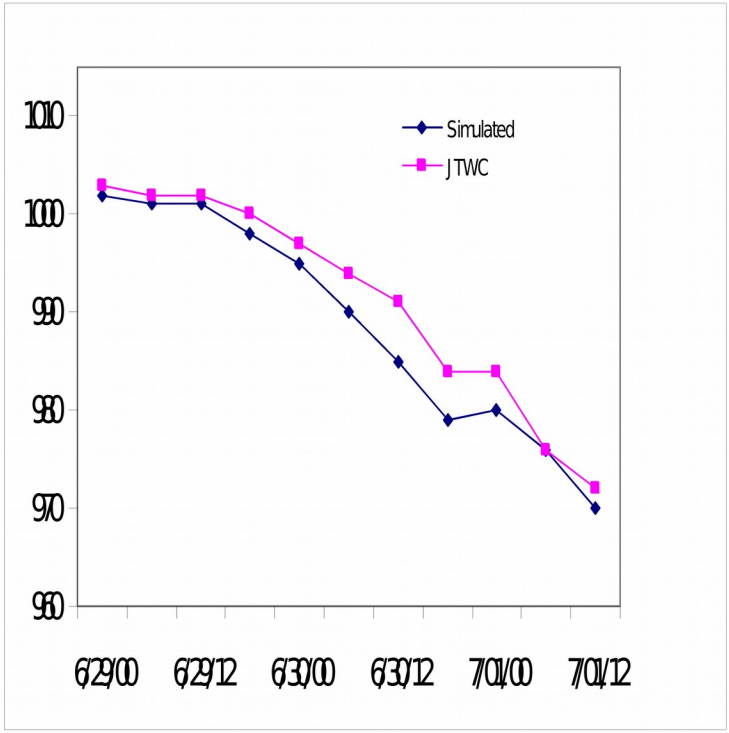
12 TCs were verified during TCS-08



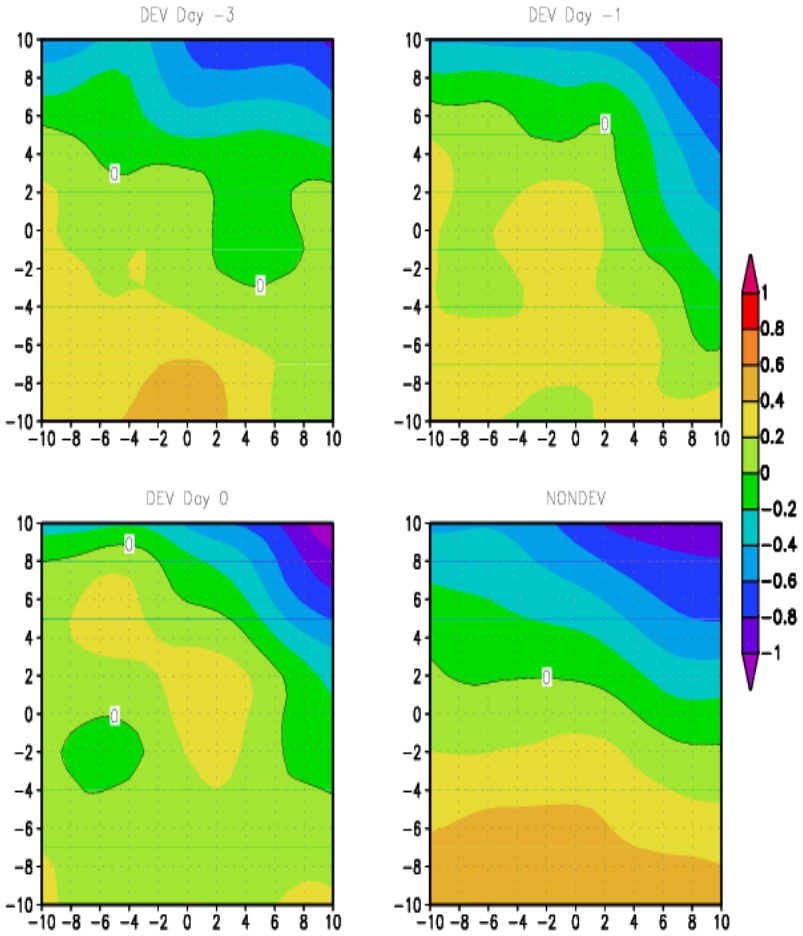
http://www.nrlmry.navy.mil/TCS.htm

Thank you


25N
20N
15N
10N
105E
110E
115E
120E
125E
JTWC


1010
1000
990
980
970
960
Simulated
JTWC
6/29/00
6/29/12
6/30/00
6/30/12
7/01/00
7/01/12

Composite of 500mb temperature anomalies



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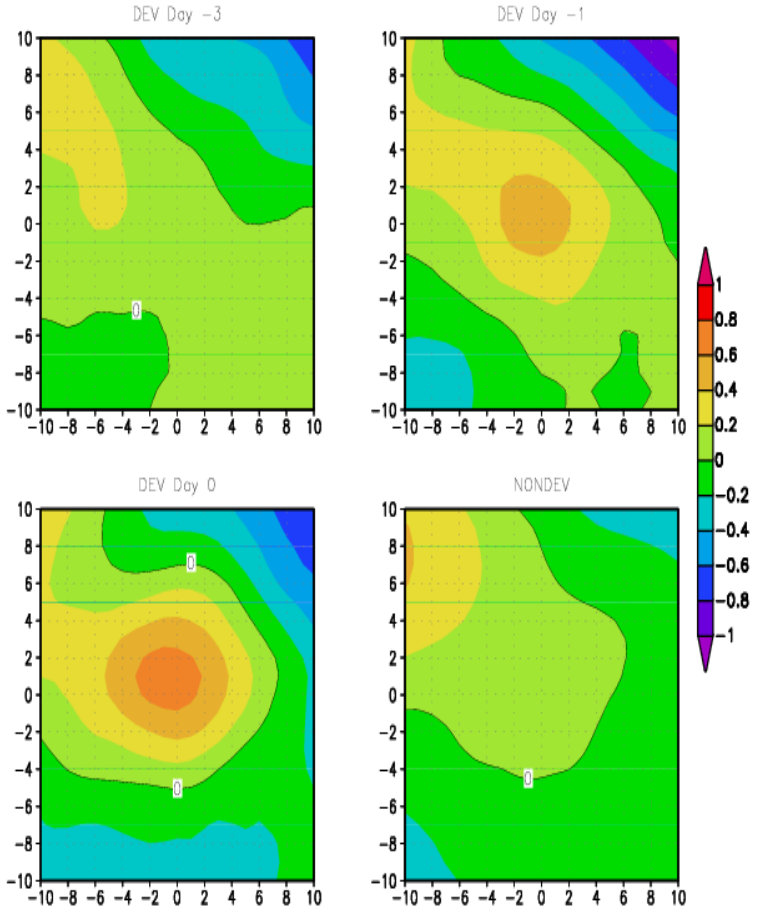
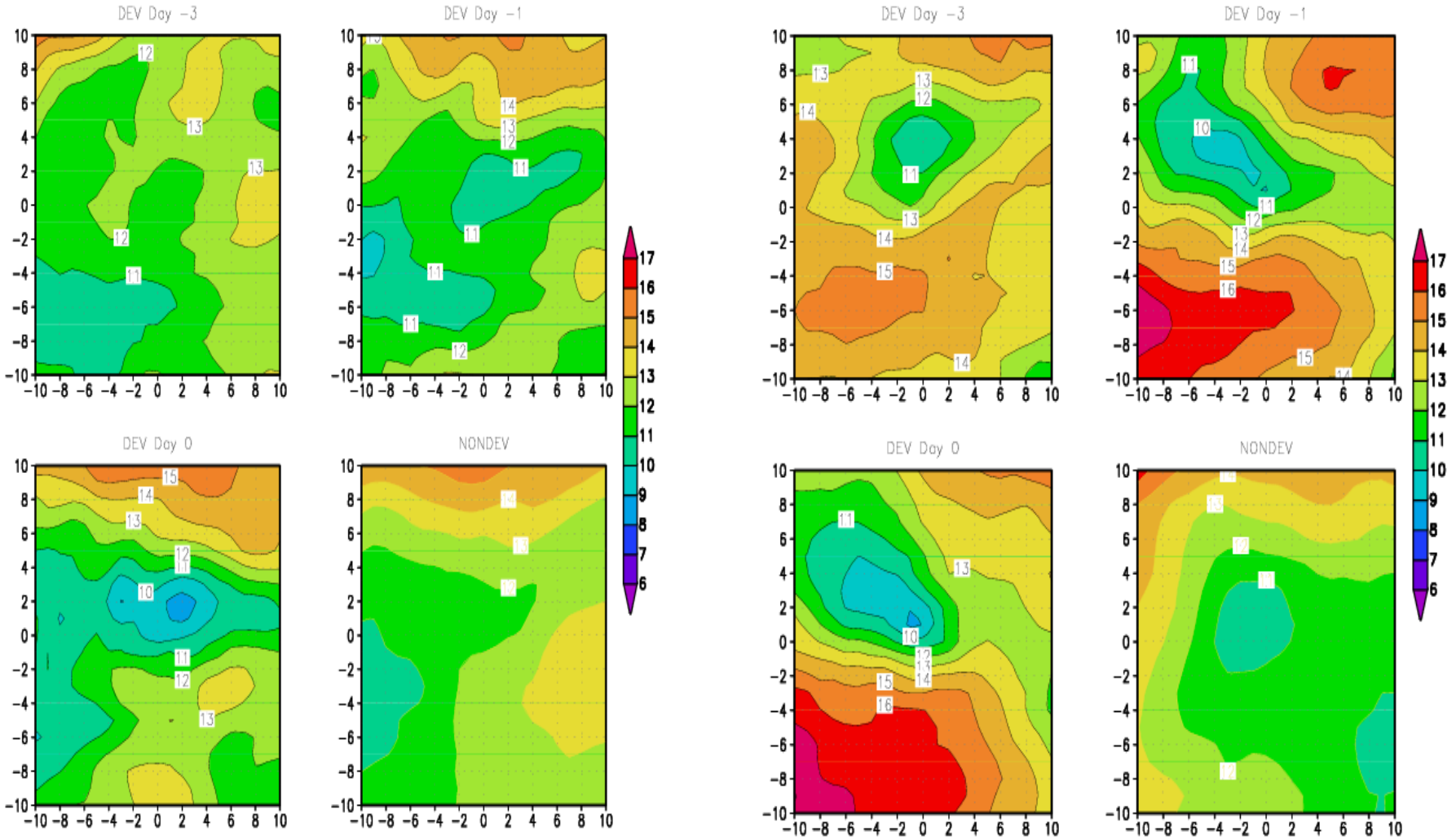


WNP

Composite of 200-850mb shear speed



NA

WNP

Multiple linear regression model for WNP

1. Selected variables for WNP
Mvspd, vor850, div850, rhum500
2. Predictors
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x2=vor850 (pattern correlation)
x3=div850 (ave [20x20 box])
x4=div850 (pattern correlation)
x5=rhum500 (ave [20x20 box])
x6=rhum500(pattern correlation)
x11=mvspd

Thresholds for TC genesis:
500mb relative humidity(20x20ave): >0.6
Mvspd: (P(-2)-P(-1)))/1day <15m/s
Vor850(10x10max): >3.167e-5
Div850(20x20ave): <0

Composite of dev (day -1)

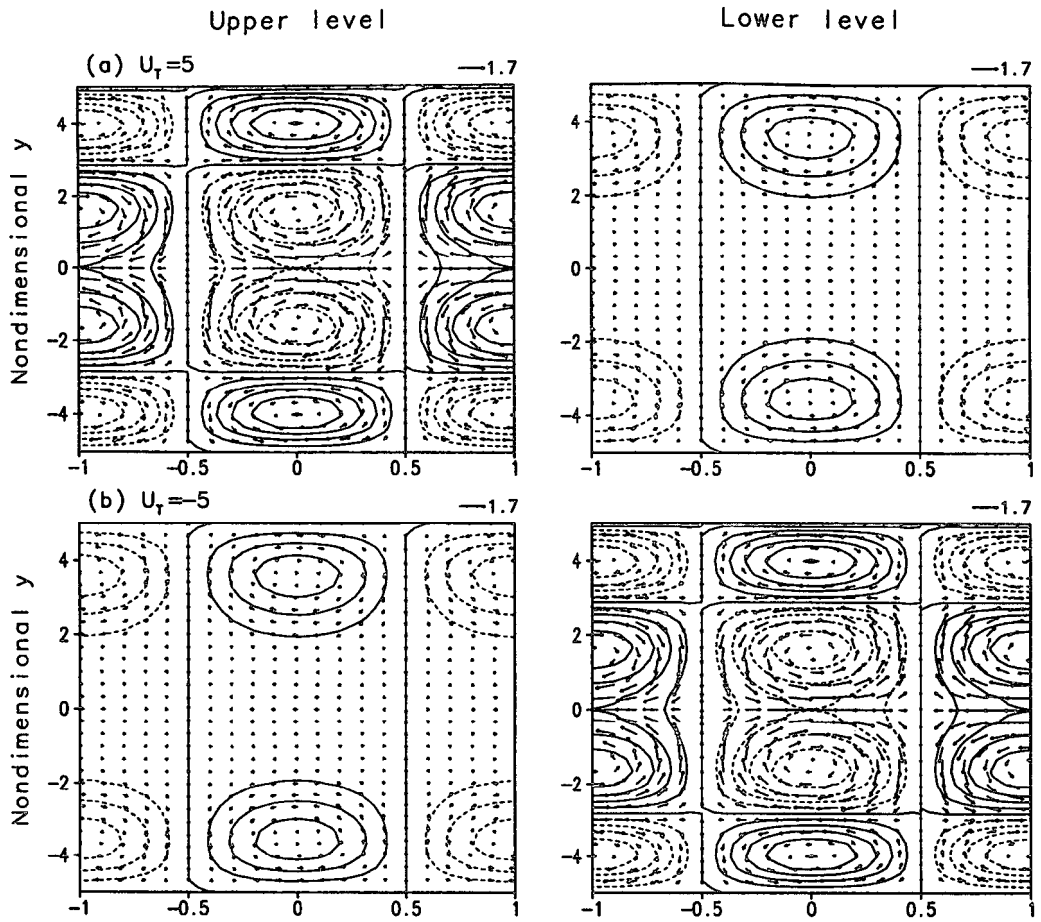
x1,x3,x5,x11 will be normalized before they are input into regression equation

Vor850,rhum850,Mvspd:
Z = (X-Xmin)/(Xmax-Xmin)
Div850:
Z = (X-Xmax)/(Xmin-Xmax)

b1=0.074, b2=0.187, b3=0.269, b4=1.195
b5=-0.178,b6=-0.070,b7=-0.049

We use samples from 2003-2005 as the input to derive the prediction model.
Currently only to predict 24-48 hours TC genesis events

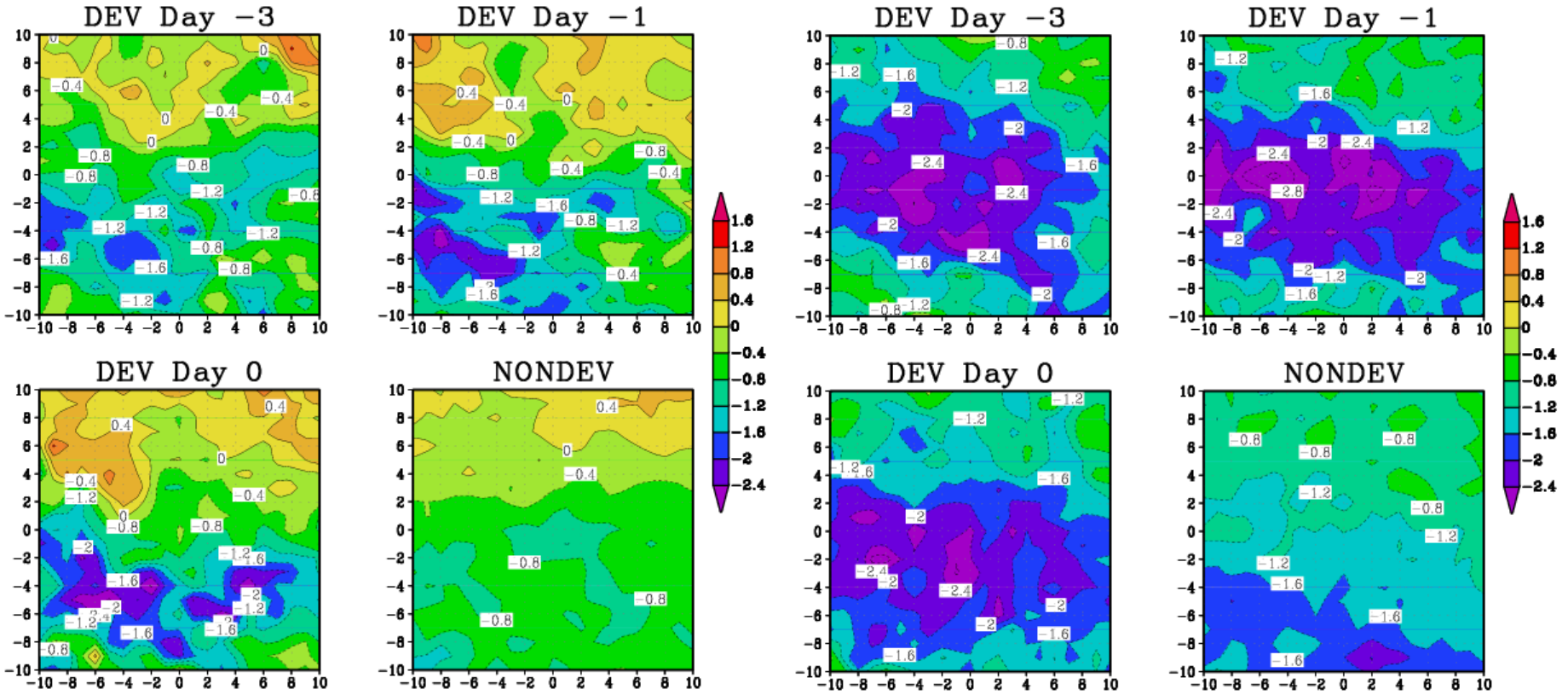
Easterly shear favors the amplification o Rossby wave in lower troposphere



An easterly shear leads to the amplification of Rossby waves at lower levels, whereas a westerly shear favors the amplification of Rossby waves at upper levels.

Wang and Xie (1996)

-day low-pass filtered 850mb convergence/divergence (10^{-6} s



NA

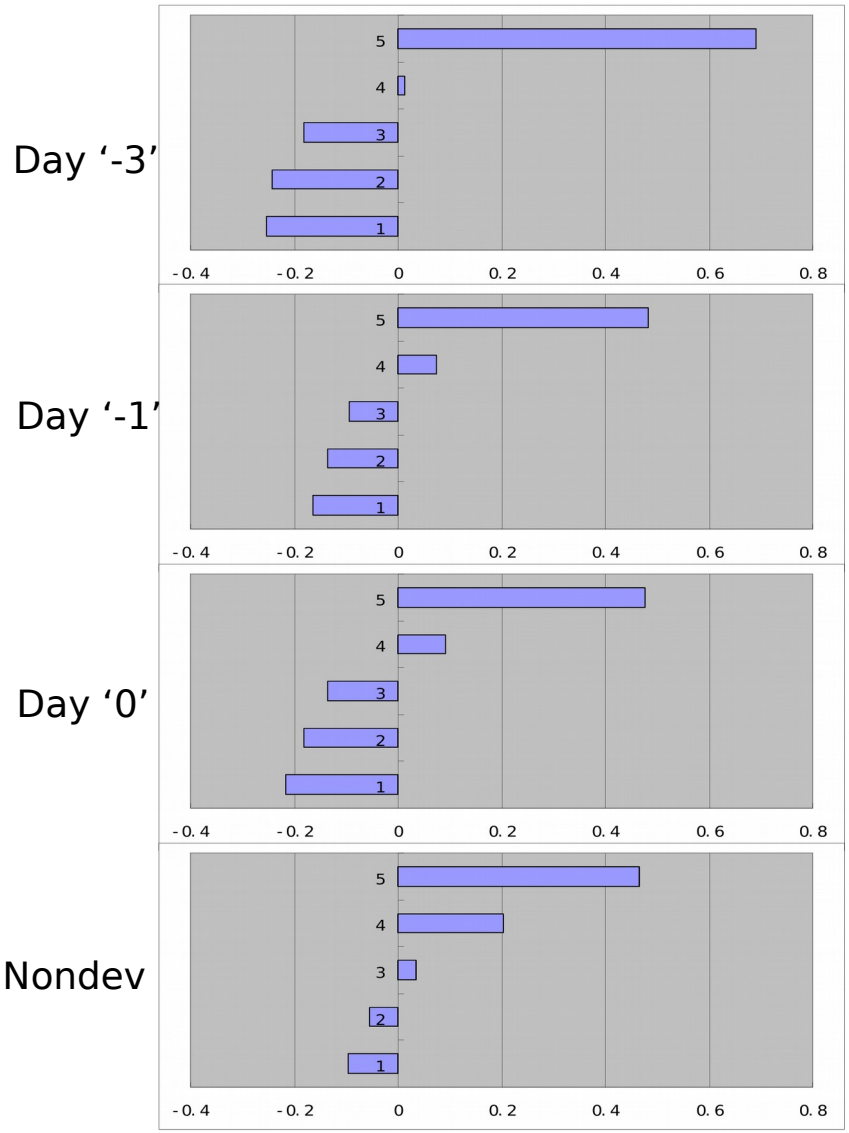
-0.655	-0.623
-0.659	-0.459

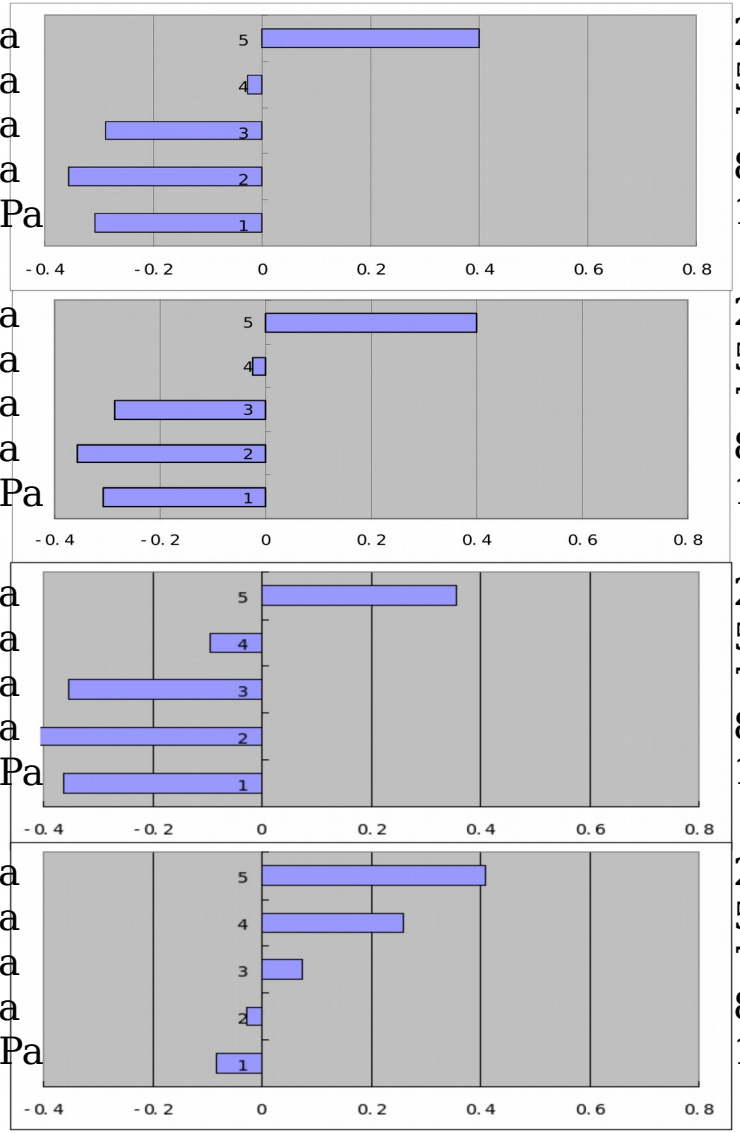
WNP

-1.530	-1.619
-1.614	-1.268

Dev vs Nondev: Stronger convergence for both basins

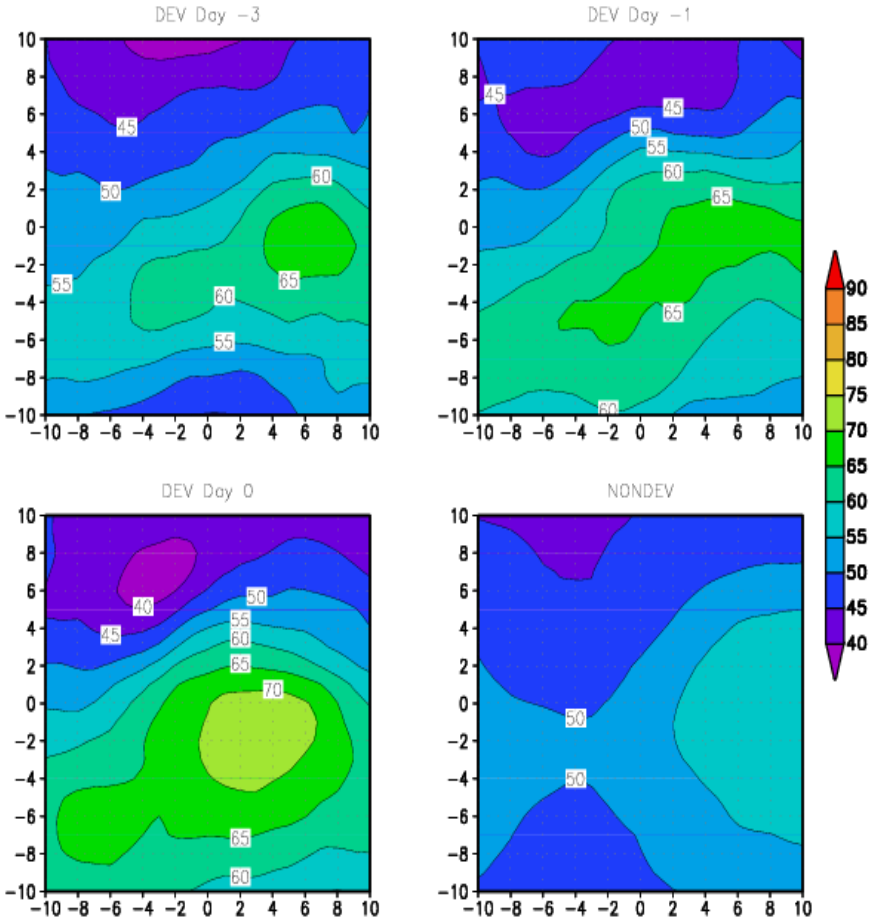
ertical profile of 10° x 10° domain averaged 20-day low-pass filtered du/



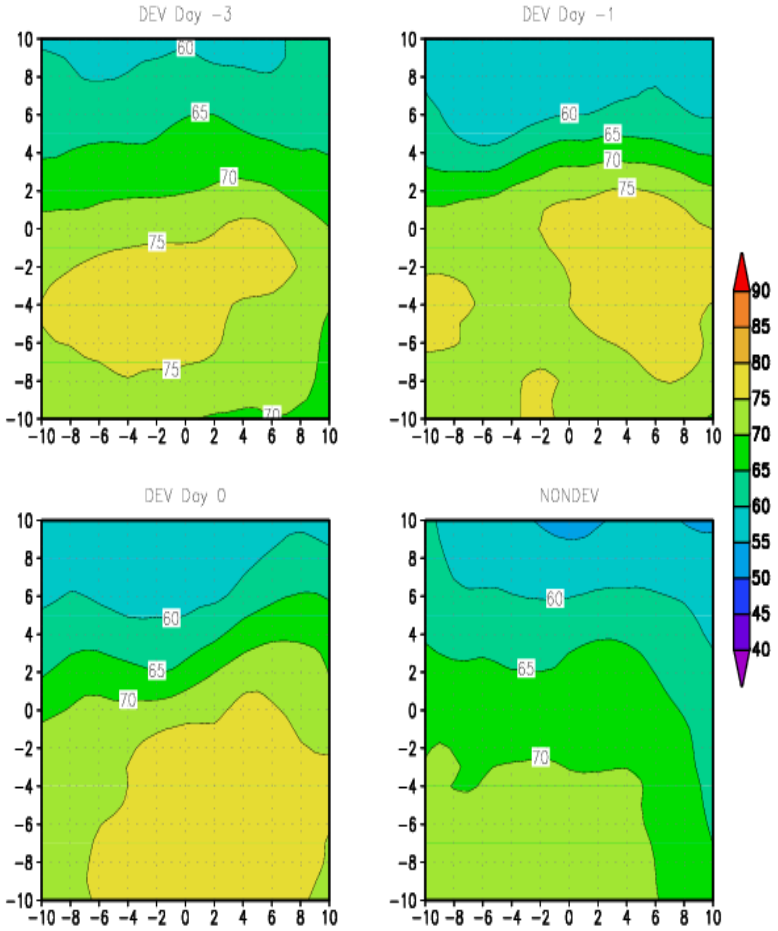


NA

Composite of 500mb relative humidity



NA



WNP